

# REPORT DOCUMENTATION PAGE

Public reporting burden for this collection of information is estimated to average 1 hour per response, including the time for reviewing instructions, gathering existing data needed, and completing and reviewing this collection of information. Send comments regarding this burden estimate or any other aspect of this burden to Department of Defense, Washington Headquarters Services, Directorate for Information Operations and Reports (0704-0188), 4302. Respondents should be aware that notwithstanding any other provision of law, no person shall be subject to any penalty for failing to comply with a collection of information if it does not have a valid OMB control number. PLEASE DO NOT RETURN YOUR FORM TO THE ABOVE ADDRESS.

AFRL-SR-AR-TR-03-

0386

<b>1. REPORT DATE (DD-MM-YYYY)</b> 24-09-2001		<b>2. REPORT TYPE</b> Technical Progress Report		Oct 2000 through (Sept 2001)	
<b>4. TITLE AND SUBTITLE</b>  The ActComm Project on Transportable Agents and Wireless Networks. 1997 AFOSR MURI Award				<b>5a. CONTRACT NUMBER</b>	
				<b>5b. GRANT NUMBER</b> F49620-97-1-0382	
				<b>5c. PROGRAM ELEMENT NUMBER</b>	
<b>6. AUTHOR(S)</b>  George Cybenko, Dorothy and Walter Gramm Professor of Engineering Principal Investigator				<b>5d. PROJECT NUMBER</b>	
				<b>5e. TASK NUMBER</b>	
				<b>5f. WORK UNIT NUMBER</b>	
<b>7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)</b>  Thayer School of Engineering Hanover NH 03755 8000 Cummings Hall Dartmouth College				<b>8. PERFORMING ORGANIZATION REPORT NUMBER</b>  536128	
<b>9. SPONSORING / MONITORING AGENCY NAME(S) AND ADDRESS(ES)</b>  Air Force Office of Scientific Research 801 N. Randolph St. Arlington, VA 22203-1977				<b>10. SPONSOR/MONITOR'S ACRONYM(S)</b>	
				<b>11. SPONSOR/MONITOR'S REPORT NUMBER(S)</b>	
<b>12. DISTRIBUTION / AVAILABILITY STATEMENT</b> Unlimited Distribution <div style="text-align: center;"><b>DISTRIBUTION STATEMENT A</b> Approved for Public Release Distribution Unlimited</div>					
<b>13. SUPPLEMENTARY NOTES</b>					
<b>14. ABSTRACT</b>  The goal of the ActComm project is to develop technologies that will maximize the usability of complex, global computer and communications networks, focusing especially on wireless networks, for modern command-and-control applications. The main technical innovation is the concept of an active communications system. An active communications system consists of dynamic elements - Active software, active information, active hybrid networks and active resource allocation. These active elements are introduced to make future military wireless computer and communications networks more robust, more powerful and more flexible under a wide variety of operating environments. Active elements will be coordinated by a novel architecture that uses advanced agents to manage network, computer and information assets delivering high confidence communications and computing.					
<b>15. SUBJECT TERMS</b>					
<b>16. SECURITY CLASSIFICATION OF:</b>			<b>17. LIMITATION OF ABSTRACT</b>	<b>18. NUMBER OF PAGES</b>	<b>19a. NAME OF RESPONSIBLE PERSON</b> George Cybenko
<b>a. REPORT</b> Unclassified	<b>b. ABSTRACT</b> Unclassified	<b>c. THIS PAGE</b> Unclassified			<b>19b. TELEPHONE NUMBER (include area code)</b> 603 646-3843

20031006 046

**ActComm Project Technical Report for FY2001***Submitted by:*

George Cybenko (Principal Investigator)  
Thayer School of Engineering  
Dartmouth College  
Hanover, NH 03755-8000

Grant Number F49620-97-1-0382, Air Force Office of Scientific Research

**Table of Contents**

Overview  
Personnel  
Publications  
Students Supported  
Presentations  
Transitions

---

**ActComm Project Technical Progress Summary: Overview**

The ActComm Project is a Department of Defense Multidisciplinary University Research Initiative effort administered by the Air Force Office of Scientific Research. ActComm's goals are to research and develop technologies that will make volatile networks, especially wireless networks, more robust using mobile agent software systems. The five-year project began in the summer of 1997.

A complete description of our planning, execution, analysis and presentation of the experiment can be found at

<http://actcomm.dartmouth.edu/demo2/>

and

<http://actcomm.dartmouth.edu/~rgray/present/muri2001review.ppt>

The project website is at <http://actcomm.dartmouth.edu/> with additional information about the project's main agent system, D'Agents, at <http://agent.cs.dartmouth.edu/>.

According to the project's original schedule, year 4 of the effort was to be devoted to research integration and evaluation in testbed experiments, leading to a culminating experiment in the 5th year. In addition to the basic research activities which are documented below, project personnel have been working this year to integrate a variety of systems developed during the first 3 plus years, including advanced information retrieval techniques, resource allocation and control, network sensing and prediction, ad hoc wireless routing and the underlying mobile agent technology. A preview of this culminating experiment will be presented at the December 13, 2001 technical program review meeting to be held in Arlington, VA.

Project personnel by institution are:

**DISTRIBUTION STATEMENT A**  
Approved for Public Release  
Distribution Unlimited

Dartmouth: G. Cybenko, R. Gray, S. McGrath, D. Kotz, D. Rus  
Harvard: H.T. Kung  
University of Illinois at Urbana-Champaign: G. Agha, T. Basar, P.R. Kumar  
RPI: K. Vastola  
ALPHATECH: A. Evans  
Lockheed Martin: J. Daniels

---

## PUBLICATIONS

---

R. S. Gray and G. Cybenko and D. Kotz and D. Rus. Mobile agents: Motivations and State of the Art. In Jeffrey Bradshaw, editor, Handbook of Agent Technology, AAAI/MIT Press, 2001. Accepted for publication. Draft available as Technical Report TR2000-365, Department of Computer Science, Dartmouth College.

<http://agent.cs.dartmouth.edu/papers/#gray:motivation>

R. S. Gray and D. Kotz and R. A. Peterson, Jr. and J. Barton and D. Chacon and P. Gerken and M. Hofmann and J. Bradshaw and M. Breedy and R. Jeffers and N Suri. Mobile-Agent versus Client/Server Performance: Scalability in an Information-Retrieval Task. In Proceedings of the Fifth IEEE International Conference on Mobile Agents, Atlanta, Georgia, December, 2001. Springer-Verlag. Accepted for publication.

<http://agent.cs.dartmouth.edu/papers/#gray:scalability>

R S. Gray and D Kotz and R. A. Peterson, Jr. and P. Gerken and M. Hofmann and D. Chacon and Greg Hill and Niranjan Suri. Mobile-Agent versus Client/Server Performance: Scalability in an Information-Retrieval Task. Technical Report TR2001-386, Dept. of Computer Science, Dartmouth College, January, 2001.

<http://agent.cs.dartmouth.edu/papers/#gray:scalability-tr>

R. S. Gray and G. Cybenko and D. Kotz and R.A. Peterson and D. Rus. D'Agents: Applications and Performance of a Mobile-Agent System. Submitted to Software Practice and Experience, May, 2001.

<http://agent.cs.dartmouth.edu/papers/#gray:spe>

D. Kotz and G. Jiang and R. Gray and G. Cybenko and R.A. Peterson. Performance Analysis of Mobile Agents for Filtering Data Streams on Wireless Networks. In Proceedings of the Workshop on Modeling, Analysis and Simulation of Wireless and Mobile Systems (MSWiM 2000), pages 85-94, August, 2000. ACM Press.

<http://agent.cs.dartmouth.edu/papers/#kotz:jmodel>

D. Kotz and G. Jiang and R. Gray and G. Cybenko and R.A. Peterson. Performance Analysis of Mobile Agents for Filtering Data Streams on Wireless Networks. Technical Report TR2000-366, Dept. of Computer Science, Dartmouth College, May, 2000.

<http://agent.cs.dartmouth.edu/papers/#kotz:model-tr2>

J. Bredin and D. Kotz and D. Rus and R.T. Maheswaran and C. Imer and T. Basar. A Market-Based Model for Resource Allocation in Agent Systems. In Franco Zambonelli, editor, Coordination of Internet Agents Models, Technologies, and Applications, chapter 17, Springer-Verlag, 2001.

<http://agent.cs.dartmouth.edu/papers/#bredin:game-book>

J. Bredin and D. Kotz and D. Rus. The Role of Information in Computational-Resource Allocation, for the TASK Electronic Commerce REF. Invited paper at the DARPA TASK PI meeting, May, 2001  
<http://agent.cs.dartmouth.edu/papers/#bredin:info>

J. Bredin and D. Kotz and D. Rus and R.T. Maheswaran and C. Imer and T. Basar. Computational Markets to Regulate Mobile-Agent Systems. Autonomous Agents and Multi-Agent Systems, September, 2001. Accepted for publication.  
<http://agent.cs.dartmouth.edu/papers/#bredin:jgame>

J.L. Bredin. Market-based Control of Mobile-agent Systems. Ph.D. Thesis, Dept. of Computer Science, Dartmouth College, June, 2001. Available as Dartmouth Computer Science Technical Report TR2001-408.  
<http://agent.cs.dartmouth.edu/papers/#bredin:thesis>

Jonathan L. Bredin. Market-based Control of Mobile-agent Systems. Technical Report TR2001-408, dartmouth, June, 2001. Ph.D Dissertation  
<http://agent.cs.dartmouth.edu/papers/#bredin:thesis-tr>

O.C. Imer and T. Basar. Control of congestion in high-speed networks. European J. Control, 7:132-144, September 2001.  
URL: <http://black.csl.uiuc.edu/~tbasar/ejc2001.pdf>

O.C. Imer, S. Compans, T. Basar, and R. Srikant. ABR congestion control in ATM networks. IEEE Control Systems Magazine, 21(1):38-56, February 2001.  
URL: <http://black.csl.uiuc.edu/~tbasar/csm2001.pdf>

E. Altman, T. Basar, T. Jimenez, and N. Shimkin. Competitive routing in networks with polynomial costs. IEEE Trans. Automatic Control, 2001 (to appear).  
URL: <http://black.csl.uiuc.edu/~tbasar/tac2001.pdf>

E. Altman, T. Basar, T. Jimenez, and N. Shimkin. Routing into two parallel links: Game-theoretic distributed algorithms. Journal of Parallel and Distributed Computing, special issue on Routing in Computer and Communication Systems, 2001 (to appear).  
URL: <http://black.csl.uiuc.edu/~tbasar/jpdc2000.pdf>

J. Bredin, R.T. Maheswaran, O.C. Imer, T. Basar, D. Kotz and D. Rus. A Computational markets to regulate mobile-agent systems. Autonomous Agents and Multi-Agent Systems (currently being revised).  
URL: <http://black.csl.uiuc.edu/~tbasar/aams.pdf>

O.C. Imer, T. Basar, and R. Srikant. A distributed globally convergent algorithm for fair, queue-length-based congestion control. IEEE Transactions on Automatic Control, May 2001 (submitted)  
URL: <http://black.csl.uiuc.edu/~tbasar/tac-imer2001.pdf>

E. Altman, T. Basar, and R. Srikant. Nash equilibria for combined flow control and routing in networks: asymptotic behavior for a large number of users. IEEE Transactions on Automatic Control, May 2001 (submitted)  
URL: <http://black.csl.uiuc.edu/~tbasar/tac-combined2001.pdf>

O.C. Imer, T. Basar, and R. Srikant. A distributed globally convergent algorithm for fair, queue-length-

based congestion control. Proc. 40th IEEE Conf. Decision and Control, Orlando, Florida, December 4-7, 2001 (to appear)

URL: <http://black.csl.uiuc.edu/~tbasar/cdc01-imer.pdf>

T. Alpcan, T. Basar, R. Srikant, and E. Altman. CDMA uplink power control as a noncooperative game. Proc. 40th IEEE Conf. Decision and Control, Orlando, Florida, December 4-7, 2001 (to appear)

URL: <http://black.csl.uiuc.edu/~tbasar/cdc01-alpcan.pdf>

R. Maheswaran and T. Basar. Decentralized network resource allocation as a repeated game. Proc. 40th IEEE Conf. Decision and Control, Orlando, Florida, December 4-7, 2001 (to appear)

URL: <http://black.csl.uiuc.edu/~tbasar/cdc01-rajiv.pdf>

T.~Alpcan and T.~Basar. A variable rate model with QoS guarantees for real-time internet traffic. Proc. SPIE Internat. Symp on Information Technologies 2000, vol. 4211, Internet Performance and Control of Networked Systems, November 5-8, 2000, Boston, Massachusetts.

O.C. Imer, T. Basar, and R. Srikant. A robust adaptive algorithm for ABR congestion control in ATM networks. Proc. IEEE ICCCN2000, pp. 48-53, October 16-18, 2000, Las Vegas, Nevada.

URL: <http://black.csl.uiuc.edu/~tbasar/ICCCN2000.pdf>

Piyush Gupta and P. R. Kumar, Internets in the Sky: The Capacity of Three Dimensional Wireless Networks. Communications in Information and Systems, vol. 1, issue 1, pp. 33-49, January 2001.

Piyush Gupta and P. R. Kumar, Internets in the Sky: Capacity of 3-D Wireless Networks, pp.~2290--2295, Proceedings of the 39th IEEE Conference on Decision and Control, Sydney, Australia, Dec. 2000.

P. R. Kumar, New Technological Vistas for Systems and Control: The Example of Wireless Networks. IEEE Control Systems Magazine, pp. 24--37, vol. 21, no. 1, Feb. 2001.

V. Kawadia, S. Narayanaswamy, R. Rozovsky, R. S. Sreenivas and P.R. Kumar, Protocols for Media Access Control and Power Control in Wireless Networks. To appear in Proceedings of the 40th IEEE Conference on Decision and Control, Orlando, FL, Dec. 4--7, 2001.

Kung, H. T. and Vlah, D. (2001). Geographically Guided Routing for Sensor Networks. Submitted to Infocom 2002, August 2001.

Hsiao, P. H., Kung, H. T., and Tan, K-S. (2001). TCP with Sender-Based Delay Control. Submitted to Infocom 2002, August 2001.

Hsiao, P. H., Kung, H. T., and Tan, K-S. (2001). Active Delay Control for TCP. IEEE Globecom 2001, November 2001.

Hsiao, P. H. (2001). Geographical Region Summary Service for Geographical Routing. The ACM Symposium on Mobile Ad Hoc Networking & Computing (MobiHoc 2001) Poster Paper, October 2001.

Chen, Z. D., Kung, H. T. and Vlah, D. (2001). Ad Hoc Relay Wireless Networks over Moving Vehicles on Highways. The ACM Symposium on Mobile Ad Hoc Networking & Computing (MobiHoc 2001) Poster Paper, October 2001.



Kung, H. T., et al. (2001). MotusNet: A Content Network. Submitted to SIGCSE 2002.

Hsiao, P. H., Kung, H. T., and Tan, K-S. (2001). Video over TCP with Receiver-based Delay Control. 11th International Workshop on Network and Operating Systems Support for Digital Audio and Video (NOSSDAV 2001), 199-208.

Hsiao, P. H., Hwang, A., Kung, H. T., and Vlah, D. (2001). Load-Balancing Routing for Wireless Access Networks. Proceedings of IEEE INFOCOM'01 (The Conference on Computer Communications), 986-995.

Wang, S. Y., and Kung, H. T. (2001). Use of TCP Decoupling in Improving TCP Performance over Wireless Networks, Wireless Network, 7 (2001), 221-236.

Hsiao, P. H., Hwang, A., Kung, H. T., and Vlah, D. (2000). Wireless Open Service Networks. Proc. IEEE GLOBECOM '00 Workshop on Service Portability and Virtual Customer Environments, 62-68.

L.A. Shay and K.S. Vastola. The Wireless Network Environment Sensor: Principles and Practice, RPI Networks Lab tech. rep.

L.A. Shay. Determination of an Appropriate Order for the Autoregressive Model for the WiNE Sensor Baseline, working paper.

L.A. Shay. The Wireless Network Environment Sensor, PhD Thesis Proposal draft.  
Above available from <http://networks.ecse.rpi.edu/~shay/>

B. Sikdar and K. S. Vastola. The Effect of TCP on the Self-Similarity of Network Traffic, Proceeding of 35th Conference on Information Sciences and Systems, Baltimore, MD, March 2001.

B. Sikdar and K. S. Vastola. On the Contribution of TCP to the Self-Similarity of Network Traffic, To appear in the Proceedings of the International Workshop on Digital Communications, Taormina, Italy, September 2001. Invited paper to be published by Springer-Verlag.

G. Cybenko and G. Jiang, Developing a Distributed System for Infrastructure Protection, IEEE IT Professional, vol .4, pp.17-22, July/August,2000

G. Cybenko, Sullivan F, Tomorrow's hardest problems. Comput. Sci. Eng. 3 (3): 40-41 May-June, 2001.

G. Cybenko, Reducing quantum computations to elementary unitary operations. Comput. Sci. Eng. 3 (2): 27-32 Mar. - Apr. 2001.

G. Cybenko, The new millennium challenge. Comp. Sci. Eng. 2 (6): 4-5 Nov.-Dec. 2000.

G. Cybenko. Who wants more? Comput. Sci. Eng. 2 (4): 3-3 Jul.-Aug. 2000.

B.E. Brewington, Cybenko, G. How dynamic is the Web? Comput. Newtw. 33 (1-6): 257-276 Jun. 2000.

XML-RPC Agents for Distributed Scientific Computing, with K. Gallivan et al, IMACS 2000.

G. Jiang, G. Cybenko and D. McGrath, Infrastructure web: distributed monitoring and managing critical infrastrcutres, Proc. of SPIE symposium on Law Enforcement Technologies, Boston, Nov 2000.

---

## **STUDENTS SUPPORTED FY 2001**

---

### **Dartmouth**

*Graduate Students:* J. Bredin, G. Nofsinger, Q. Li, R. Xie

*Undergraduate Students:* D. Walsh, W. Pierce, C. Masone, M. Corr, N. Dubrovsky, D. Zlateva, A. Fiske, R. Neelakantan

### **University of Illinois**

R.A. Rozovsky, R. Maheswaran, T. Alpcan

### **Harvard**

D. Vlah, D. Cheng, P.-H Hsiao

### **Rensselaer Polytechnic Institute**

*Graduate Students:* L.A. Shay, B. Sikdar

---

## **PRESENTATIONS By ActCom Participants in FY 2001**

---

International Neural Network Society Board of Governors meeting, Como, Italy, July 2000.

DARPA ISAT Final Briefing, Woods Hole MA, August 2000.

AFOSR Strategic Planning Meeting, La Jolla, CA, August 2000.

Modeling and monitoring change on the Web, Lorentz Institute, Leiden University, Netherlands, Sept, 2000.

Agent-based systems engineering, DARPA TASK Meeting, Charleston SC, October 2000.

AFOSR MURI Review, Harvard University, November 2000.

The Infrastructure Web, SPIE, Boston MA, November 2000.

Mathematics of the changing Web, Institute for Mathematics and its Applications, University of Minnesota, Feb, 2001.

An overview of electronic crime, CNRI, Pisa Italy March 2001.

Modeling Web changes, CNRI, Pisa Italy March 2001.

Critical Infrastructure Protection Research and Training Needs, White House Conference Center, June 2001.

DARPA CoABS PI meeting, February 2001

DARPA TASK PI meeting, May 2001

Mitsubishi Electric Research Lab, May 2001

DARPA CoABS PI meeting, July 2001

40<sup>th</sup> IEEE Conference Decision and Control, Orlando, FL Dec. 4-7, 2001

Internet Performance and Control of Networked Systems, Boston, MA, November 5-8, 2001

IEEE ICCCN2000, Las Vegas, Nevada, October 16-18, 2001

ITCom 2001, Denver, August 20-24, 2001

Stochastic Theory and Control Workshop, Lawrence, Kansas, October 18-20, 2001

NSF Workshop on an Infrastructure for Mobile and Wireless Systems , The Convergence of Information Technologies and Communications, Scottsdale, Arizona, October 15, 2001.

ITCOM + OPTICOMM 2001: The Convergence of Information Technologies and Communications, Denver, August 19-24, 2001

IMA 2001 Summer Program: "Hot Topics" Workshop: Wireless Networks, August 8-10, 2001

2001 SIAM Annual Meeting, San Diego, California, July 9-13, 2001

Symposium on Complex Systems Modeling and Optimization in the Information Age To Celebrate 45 Years of Outstanding Contribution of Prof. Yu-Chi "Larry" Ho, Harvard University, June 23-24, 2001

NSF/ONR Workshop on Cross-Layer Design in Adaptive Ad Hoc Networks: From Signal Processing to Global Networking, Cornell University, May 31-June 1, 2001,

Seminar at Univ. of California, Santa Barbara

FUNDAMENTAL SCALING LAWS FOR WIRELESS NETWORKS: HOW MUCH TRAFFIC CAN THEY CARRY?

The United Technologies Sponsored Seminar Series in Manufacturing and Systems, Boston University, September 21, 2001

Seminar at Harvard University, September 19, 2001, SCALING LAWS FOR WIRELESS NETWORKS: HOW MUCH TRAFFIC CAN THEY CARRY?

Seminar at MIT: LIDS Colloquium, September 18, 2001, Ad hoc wireless networks: Analysis, protocols, architecture, and convergence



Seminar at Univ of Pennsylvania, September 17, 2001, Ad Hoc Wireless networks: Analysis, protocols, architecture, and convergence

The ACM Symposium on Mobile Ad Hoc Networking & Computing (MobiHoc 2001)

11th International Workshop on Network and Operating Systems Support for Digital Audio and Video (NOSSDAV 2001)

IEEE INFOCOM'01 (The Conference on Computer Communications)

IEEE GLOBECOM '00 Workshop on Service Portability and Virtual Customer Environments

Santa Fe Institute

National University of Singapore

Academia Sinica, Taiwan

Nortel Networks

Microsoft Corporation

---

### **Consultative and Advisory Functions**

---

Board of Visitors, Program Review of 6.1 ARL-ARO Mathematics Division, U.S. Army Research Office Research Triangle Park, NC

U.S. Army Research Office, Computing and Information Sciences Division, Panel Member, Triennial Research Strategy Planning Workshop, Charleston, SC Jan 3-5, 2001

Kansas Technology Enterprise Corporation, April 12, 2001. Review of Telecommunications and Information Sciences Laboratory at the University of Kansas

Greater Boston Biodefense Collaborative Advisory, January 24, 2001. Review of Biodefense Initiatives

Consultant to Nortel Networks, Trebia Networks, InfiniSwitch Corporation, ITServ, Nimble MicroSystem etc.

---

### **DOD and Other Transitions FY 01**

---

New CECOM project based on ActComm results (bio-medical sensing; eventual transition to LandWarri

Ongoing CoABS project (a DARPA research program on control of agent-based systems)

Ongoing TASK project (a DARPA research program on taskable agents)

New NASA project dealing with long-duration space flight (bio-medical sensing)

K.S. Vastola started Premonitia, Inc. in Acton, MA to develop technology for internet network management based in part on work under the MURI project

In July 2001, Major Shay transitioned to the faculty of the Department of Electrical Engineering and Computer Science at the United States Military Academy at West Point. She will continue to do research in fault sensing in wireless networks and wireless network security for the Information Technology and Operations Center at West Point

---

### **Honors and Awards FY 01**

---

Tamer Basar - Election to the National Academy of Engineering, 2000

IEEE Millennium Medal, 2000

President, IEEE Control Systems Society, 2000